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[redacted] 3708-62
Copy 2 of 4

18 October 1962

MEMORANDUM FOR: Director, NPIC

25X1A

ATTENTION : [redacted]

THROUGH : Assistant Director, OSA

SUBJECT : (1) Phase 1. Final Status Report
Contract No. BB-425, T.O. No. 4
Image Enhancement

(2) Contractor's Request for Change in Scope

1. Forwarded herewith for your information and file are two (2) copies of the subject report covering Phase I of T.O. 4 through the period 31 August 1962.

2. As indicated in the Contractor's transmittal letter, as well as in the text of the report, the results of Phase I preclude any further consideration of Phase II as planned. Consequently, upon your concurrence that the technical conclusions reached in the report are correct, this office will take the necessary action to terminate this Task.

3. You will note that the Contractor has suggested that the remaining funds be utilized in a program of instrument modification and improvement designed primarily to achieve greater simplicity of operation.

4. While such a program might be of some interest to your facility, it seems sufficiently far removed from the scope of the present contract to warrant independent consideration when, and if, presented in proposal form.

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Chief, Contracts Division, OSA

Attachment: DD-250 forms
COR-1790, Encl. #1, Cys 2 and 3

CD/OSA-[redacted]
Cy 1 - NPIC
2 - CD/OSA T.O. 4 BB-425
3 - AD/OSA
4 - RB/OSA

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Handle via [redacted]
Control System

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 Encl #1

COR-1790-62

COPY 1 OF 3

9043 Status Report: Phase I, Final Report

31 August 1962

ABSTRACT

The new viewing equipment for the Image Enhancement Viewer has been installed and the system now operative with a ZOOM feature and magnifications of the aerial image possible out to 90x. A new 70mm film format provides simplified recording of the unmagnified aerial image, and a 35mm camera attachment to the binocular viewing system records the magnified image out to 36x. The study program to determine the feasibility of the rotating mechanical Gaussian filters showed the filters to be impractical due to the reflection or glint from the filter tip which lowered image contrast and masked all filtering effects. The collateral theoretical and experimental studies formulated image enhancement in terms of spatial filtering with the sharp cutoff, occluding filters, but requires more time for useful completion. Recommendation is made to continue work on the Image Enhancement Viewer in order to render it more useful to the contracting agency. Specific modifications to improve the equipment are suggested, with no increase in funding or extension of delivery schedule required. Completion of the theoretical and experimental studies is also recommended.

1. General Review

Phase I of this project consisted of two major efforts, one an engineering modification and instrument improvement program, the other a feasibility study. The former concerned itself with improvement of the viewing equipment of the Image Enhancement Viewer. The latter considered the possibility of frequency attenuation by means of mechanically rotating filters located in the plane of diffraction. Upon demonstration of feasibility, Phase II would incorporate these findings and replace the present filtering method with the newer types.

The letter reports submitted as per contract requirement detailed the progress in these two major areas. Progress in the theoretical aspects was also reported, and a definite analytical formulation of image enhancement was begun. A study of the performance of the occluding filters was undertaken, with the ultimate aim of a final performance evaluation. This latter study was specifically called for in the contract.

Phase I took approximately four months to complete, and a preliminary verbal report given to the contracting agency on 27 August 1962, at his facility. This present report constitutes the final, written report on Phase I activities.

2. Engineering Modifications to the Image Enhancement Viewer

In accordance with the proposal and contract statement, a ZOOM optical system was installed. This unit is a Bausch and Lomb

Tri-Ocular, permitting a more comfortable viewing arrangement than that previously employed. The eyepieces are 5x and 7.5x, and two objectives are provided on a three-unit nosepiece, one of 6x, the other of 2x. The system Zooms a factor of two, thereby giving the viewer a range of magnification of 10x to 90x. It was not practicable to provide a continuous Zoom magnification from 1 to 25 as previously intended, in view of the requisite multiple changing of objectives and eyepieces. A 35mm camera is coupled to the system, and the magnified image can be recorded. The power of this unit is 3x (simple field-flattening optics), so that the maximum magnification which can be achieved photographically is 36x.

An improved recording camera has been incorporated in the system. This is a 70mm Linhof Cine Rollex back especially adapted for the present use. Entry is provided through the back so that a microscope can be focussed on the focal plane (at 105x, nominal), and optimum placement of the aerial image on the recording film can be effected. Details of the Tri-ocular, 70mm film format, and the 35mm camera can be seen in Figure 1, a photograph of the viewing unit.

A Filar eyepiece (12.5x) is provided for one side of the binocular system and linear measurements can be made with this. The entire microscope body is mounted on a ring which contains azimuthal markings. As the microscope is rotated, angles may be read directly, and, with the aid of a vernier on the inner plate, known to one (1) angular minute. Thus, linear and angular measurements on the aerial image are now possible. These details are shown in Figure 2.

The optical constants of the Image Enhancement Viewer optical systems are detailed in Table I. This table lists all viewing optical

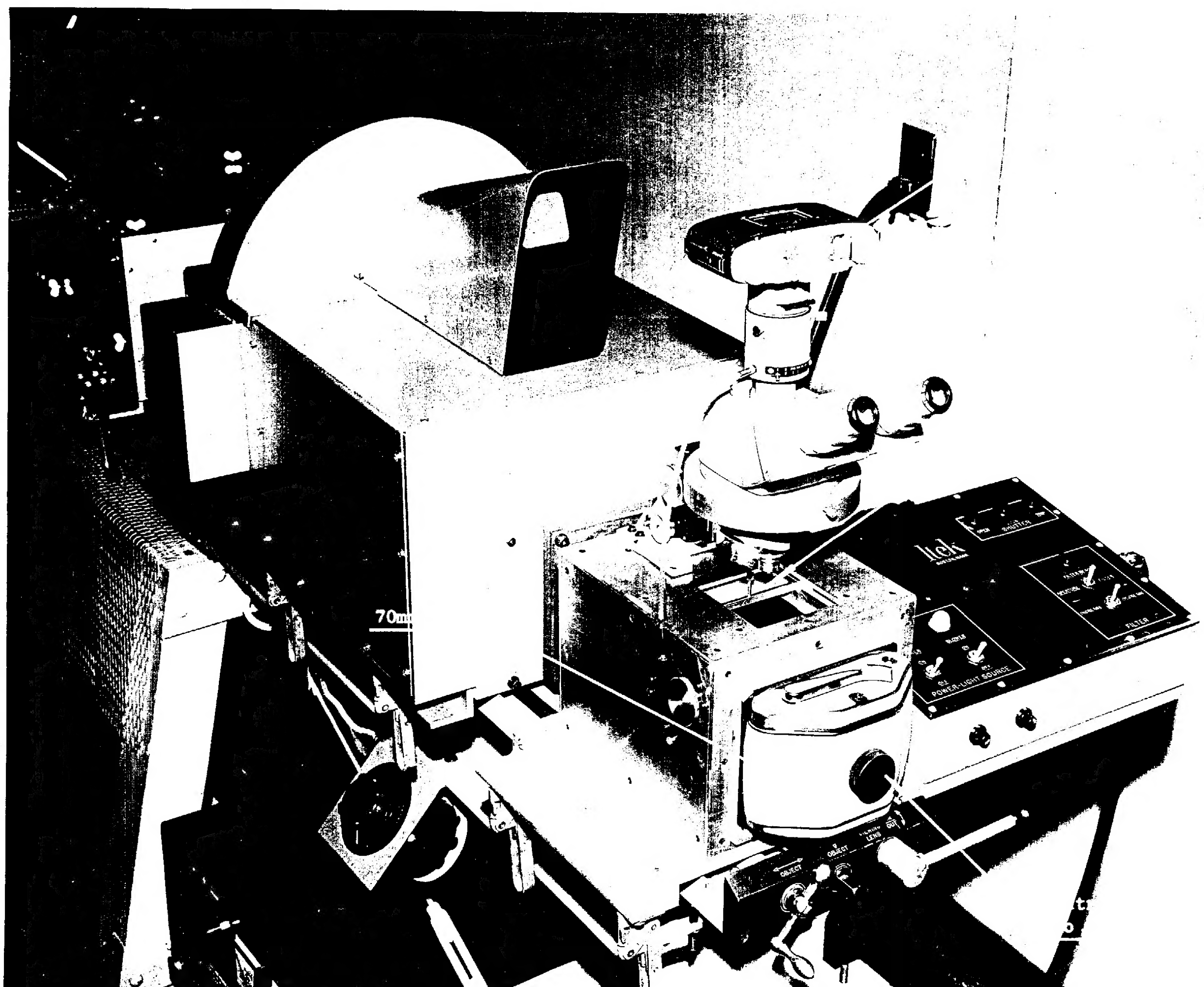

Figure 1. Photograph of the viewing [illegible] Image[illegible] in the normal viewing position showing the en[illegible] modifications to the viewing equipment.

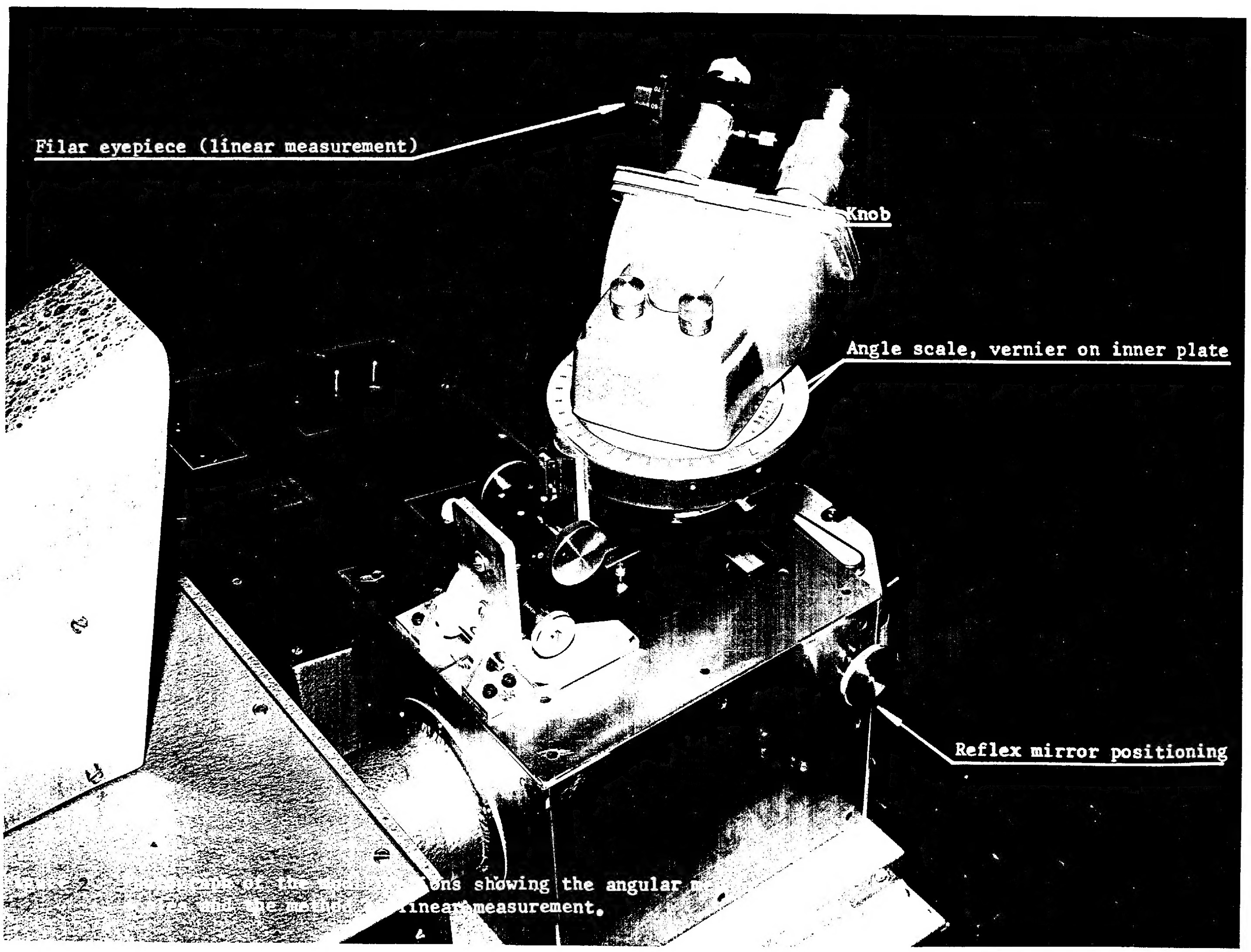

Figure 2. [illegible] of the [illegible]ons showing the angular m[illegible] [illegible] and the method [illegible] linear measurement.

TABLE I

Summary of Optical System Constants

Main optical system magnification: 1.106 (measured)

Microscope objectives: 2x, 6x, 21x*

Eyepieces (binocular): 5x, 7.5x

Filar eyepiece : 12.5x

ZOOM Range : 2x

35mm Camera Field Flattener: 3x

(Measurement on Filar eyepiece can be made to 0.01mm on aerial image in eyepiece. Actual measurement must be obtained by reduction through total system magnification.)

The viewing system has continuously variable magnification, within four steps. Using the combinations of 2x and 6x objectives, together with the 5x and 7.5x eyepieces and the 2x ZOOM, the four steps are: 1) 10x - 20x, 2) 15x - 30x, 3) 30x - 60x, and 4) 45x - 90x. The following table summarizes the extremal magnifications available for the several viewing modes. To ascertain total magnification, the magnification indicated by the combination of objective, ZOOM setting and eyepiece (or camera) must be multiplied by the main optical system magnification.

Viewing Mode	Magnification Maximum	Magnification Minimum
Visual		
Through binoculars	90	10
Glass viewing screen	1	1
Measurement (filar)	150	25
Photographic		
70mm film format	1	1
35mm camera	36	6

* The 21x objective is used for adjusting the focal plane of the 70mm film format, and is not a part of the viewing system of the microscope.

elements and tabulates the extremal magnifications available with the instrument. The main optical system magnification has been determined experimentally and is also shown.

Photographic tests were made to establish the focal plane in the 70mm film format and to check the accuracy of the optical method of adjustment. The focus is correct out to the limit of the system. The photographic tests made on the 35mm camera indicate the maintenance of correct focus. As could be expected the exposure time required to record the magnified images is considerably larger than that for the 70mm film format, nominally at unity magnification. Since the numerical aperture of the objectives is larger than that of the main optical system (an F/8 cone), the theoretical loss in image intensity is proportional to the square of the magnification (assuming no transmission losses in the optical elements). Thus, the "first-order" exposure increase for magnification of 6x and 36x would be 36 and 1296 respectively. Such increases would suggest the use of fast film. Since these photographic images will not be greatly enlarged for subsequent display and examination purposes, the grain problem ordinarily associated with fast films will not generally apply.

In addition to the viewing unit modifications, a new shutter was installed. This is a self-cocking type, adjustable from the outside of the Source Unit. It is tripped manually, at the Source Unit. Figure 3 contains a photograph of this unit and shows the significant features of the new arrangement.

As evident from Figures 1 and 2, the modifications have not been metal-finished. This was in anticipation of Phase II construction, so

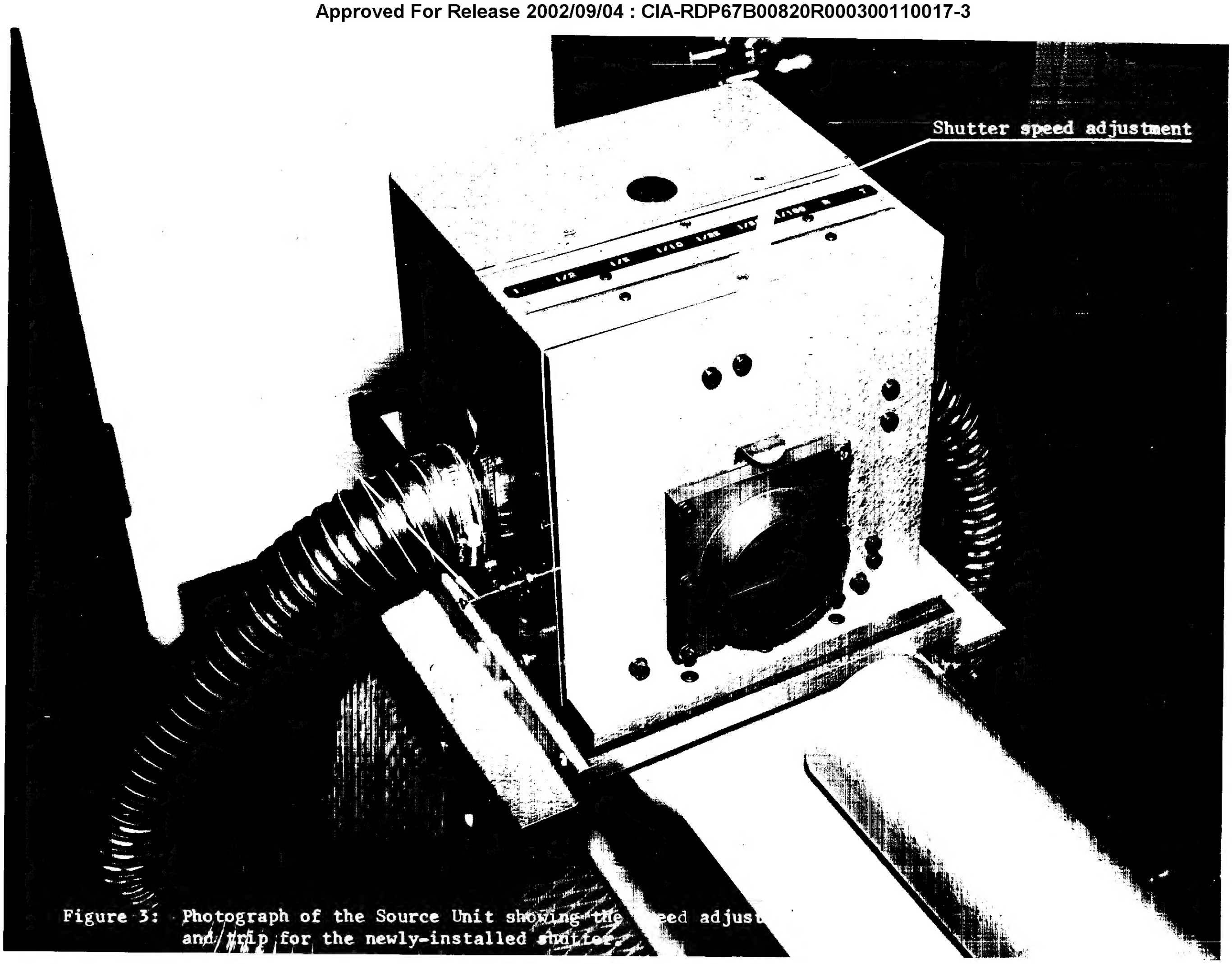

Figure 3: Photograph of the Source Unit showing the speed adjust
and trip for the newly-installed shutter.

that all parts might be metal-finished compatibly. All instrument modifications called for under Phase I have now been completed, the system calibrated and fully operative.

3. Feasibility Studies of Rotating Spatial Filters.

Introduction:

Previous development studies had demonstrated the feasibility of frequency attenuating filters, and that such filters could be fabricated from photographic materials. These filters were found to be inadequate in quality due to the deviations in glass flatness which resulted in image deformation above 40 lines/mm. It was therefore decided that application of the rotating principles through which these filters were made would be the best approach, and would be free of the objectionable features of glass placed in the plane of diffraction. Preliminary to the installation and use of such filters was the establishment of feasibility for achieving a real filtration effect and for incorporation into a semi-automatic device for insertion and use of such filters in the Image Enhancement Viewer.

The preliminary investigation therefore had three major objectives; 1) a mathematical description of the transmission characteristics of a rotating, profiled slot, 2) assuming a Gaussian cross-section, a profiled contour specification and determination of means of fabrication, and 3) the provision of a means for rotation and optical alignment which would test the feasibility of such a filter system.

The Mathematics of the Rotating Filter:

The mathematical description of the transmission characteristics of a rotating, profiled slot follows from a consideration of Figure 4. The derivation assumes bilateral symmetry for the slot not only for mathematical convenience, but also because its mechanical realization will minimize vibration, when rotated, due to small machine imbalances.

Consider the transmission lying along a circle of radius, $\bar{r}$. The arc length in the portions of Figure 4 defined by the region of T_2 is denoted $S(\bar{r})$. Then the percentage of light (transmission) which passes through the filter at the given radius, while rotating, can be written

$$T(\bar{r}) = \frac{S(\bar{r})}{\pi \bar{r}} \left\{ \frac{\sqrt{T_2} - \sqrt{T_1}}{\sqrt{T_2}} \right\} + \frac{\sqrt{T_1}}{\sqrt{T_2}}$$

in the case of amplitude weighting (coherent system illumination), or

$$T(\bar{r}) = \frac{S(\bar{r})}{\pi \bar{r}} \left\{ \frac{T_2 - T_1}{T_2} \right\} + \frac{T_1}{T_2}$$

in the case of intensity weighting (incoherent system illumination).

Now in the case of an opaque material through which the profiled slot has been cut, $T_1 = 0$, and $T_2 = 1$. If these values are substituted into the above equations, they reduce to the same result,

$$T(\bar{r}) = \frac{S(\bar{r})}{\pi \bar{r}} = \frac{\theta(\bar{r})}{\pi}.$$

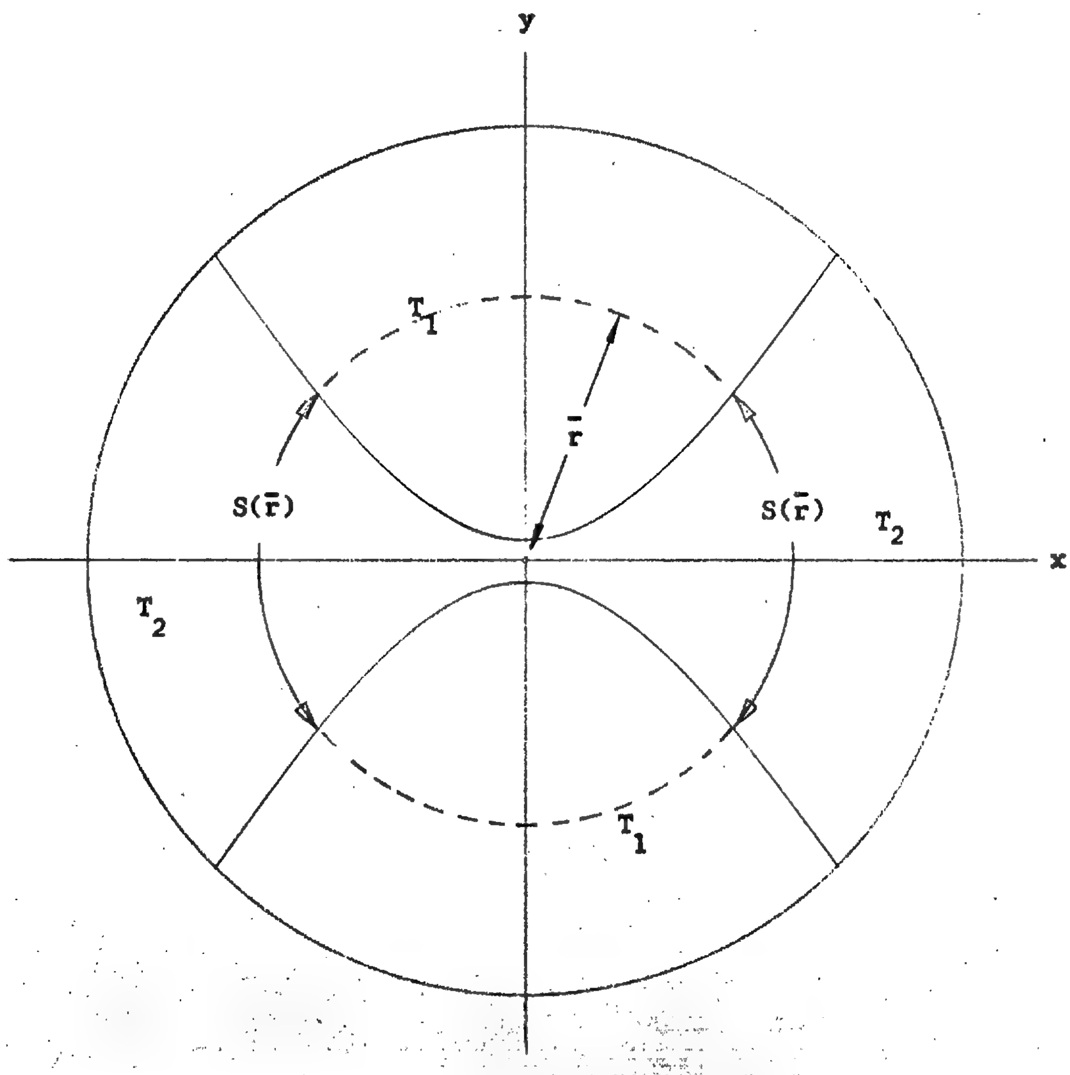

Figure 4: Diagram of a generalized slot contour. T_1 is taken to be smaller than T_2. The slot is assumed to be rotating sufficiently fast to eliminate flicker.

where $\theta(\bar{r})$ is the angular separation of the slot at a radius $\bar{r}$. This is now similar in form to the expression derived in the final report of the 9019 program (specifically, Section 3.1.3, Aperture Shape). Then only a specification of the angular spacing of the slot contour is required, and it will be valid under coherent or incoherent treatment provided the filter consists of clear and opaque sections.

It is now necessary to specify the required contour. Since it is desired to have the angular distribution as a function of the required transmission characteristics, the last equation must be transformed accordingly. Then,

$$\theta(\bar{r}) = \pi T(\bar{r}) \quad .$$

Specifications of $T(\bar{r})$ proceeds as in the 9019 Final Report, with one significant change. That report cited values of transmission which were defined for intensity-weighting. Since the plane in which the filters are to operate contains a distribution of amplitude and phase, the weighting must be on an amplitude basis. This can be accomplished mathematically by assuming the filter to introduce no more than a constant phase shift in frequency space* and taking the square root of the intensity-weighting transmission. Since this mathematical operation radically affects the analytical tractability of the integral equations governing the system imagery, the form of the filter has been changed somewhat from that developed for the 9019 program. Considered as an amplitude weighting function, the cross-

* In practice, since the slot will be composed of clear and opaque areas, this is not an assumption, because phase will be unaffected. It becomes an assumption in the case of a continuous distribution of density which has not been immersed or laminated between flats.

section of a Gaussian filter can be written

$$G(\bar{w}) = \psi_2^{1/2} - \left(\psi_2^{1/2} - \psi_1^{1/2}\right) e^{-\beta w^2}$$

where

ψ_2 = maximum transmission

ψ_1 = minimum transmission

β = filter crop-off coefficient

w = spatial frequency (radian)

Normalizing this function to the maximum value of spatial frequency passed by the optical system, and converting the frequency scale to a linear measurement, the desired angular contour relationship for the rotating Gaussian filter is given by

$$\theta(\bar{r}) = \pi\psi_2^{1/2} \left\{1 - \left(1 - \sqrt{\frac{\psi_1}{\psi_2}}\right) e^{-a\bar{r}^2}\right\}$$

where $\bar{r}$ varies from 0 to 1.0, and the equation represents the arc length defined in Figure 4. Application of the mathematical process defined in Section 2.6 of the 9019 final report (for ascertaining the optimum Gaussian filter constants) shows that equation (11) of that report changes to

$$\sqrt{\frac{\psi_1}{\psi_2}} = 1 - (\rho + 1)^{3/2} e^{-3\rho/2}$$

where $\rho = 4\beta c$, constants pertaining to input pulse and filter width. This is plotted in Figure 5.

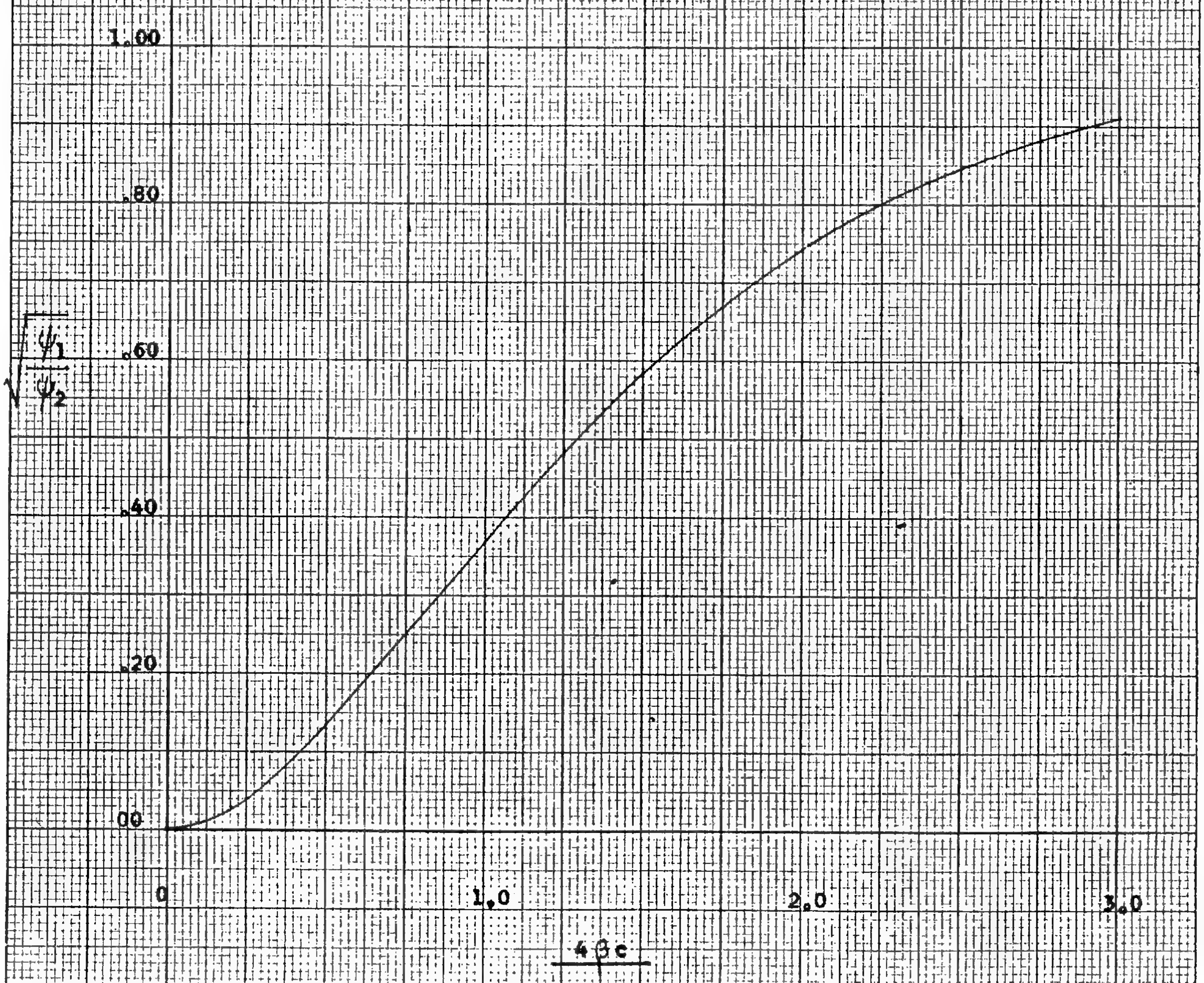

Figure 5: Plot of Optimum Filter Transmission Ratio

Using the basis for determination of the filter constants laid down in the 9019 study, and lacking suitable high-frequency content transparencies upon which to operate, it was decided to specify the filter for the feasibility tests as follows:

$$a = 64$$

$$\rho = 4\beta c = 1.0$$

To facilitate the construction of the filter so that adequate material would be available on the periphery, the decision was then made to take the maximum filter transmission equal to 50%. By Figure 5, the optimum filter ratio is 0.369. Coupled with the requirement of 50% maximum transmission, the remaining constants are:

$$\psi_2^{1/2} = 0.50$$

$$\psi_1^{1/2} = 0.1845$$

The filter contour is then plotted in Figure 6 to illustrate the general shape.

Contour specification and filter fabrication

Since it would be necessary to specify the contour in rectangular coordinates for purposes of machine-shop fabrication, a transformation of the data was necessary. Incorporating the cited filter constants, the angular relationships were transformed to rectangular through the following equations:

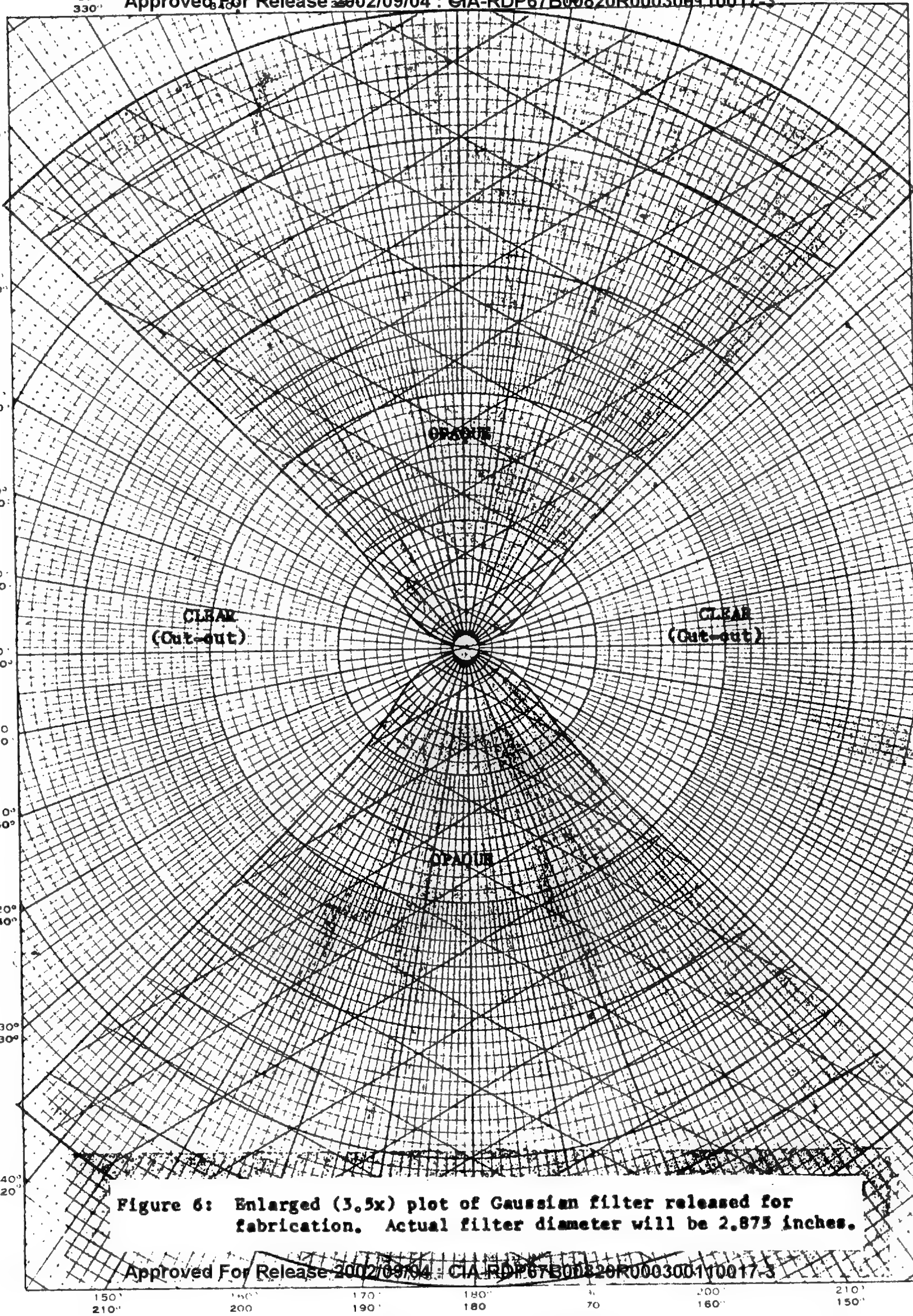

Figure 6: Enlarged (3.5x) plot of Gaussian filter released for fabrication. Actual filter diameter will be 2.875 inches.

$$x = \left(\frac{\sqrt{2}}{2}\right) \bar{r} \left\{\text{Cos A} + \text{Sin A}\right\}$$

$$y = \left(\frac{\sqrt{2}}{2}\right) \bar{r} \left\{\text{Cos A} - \text{Sin A}\right\}$$

$$A = 0.6812\ e^{-30.9716\ r^2} \quad ,$$

r now in actual physical units, inches. These points are shown in Table II, out to the region where there is no deviation from the equation $y = x$.

Considering the difficulty to be expected in mechanical centering, it was decided to make the filter in one piece, and in view of the tolerances involved, to use an electroforming technique for fabrication. Through answers to a request for quotation from outside vendors, it was ascertained that the minimum practical gap between the opaque sections of the filter was 0.003 inches, and that the contour could be held to within 0.001 inches. This necessitated a change in the contour coordinates to accomodate this gap increase. The adapter which was designed to hold the filters for rotation had four set screws located 90° apart which could be brought to bear against the outside rim of the filter and close the gap to any arbitrary setting. Then the contour coordinates were changed slightly so that when screw pressure was applied to the sides, the resultant deformation would closely approximate the correct filter. This allowed the filter to be "opened up" at the center to permit fabrication. The corrected

TABLE II

TABLE OF COORDINATES FOR GAUSSIAN SPATIAL FILTER

The following tabulation of coordinates is for the 1st Quadrant only.
(All dimensions in inches)

x	y	x	y
.000	.0005*	.172	.121
.005	.001	.177	.130
.010	.0015*	.183	.140
.020	.0025*	.188	.149
.030	.004	.199	.168
.040	.006	.210	.186
.049	.008	.221	.203
.059	.011	.233	.220
.069	.014	.245	.236
.078	.018	.258	.252
.087	.023	.271	.267
.096	.028	.284	.281
.105	.034	.298	.296
.113	.041	.312	.311
.121	.048	.326	.325
.128	.056	.354	.3535*
.135	.065	.382	.382
.142	.074	⋮	⋮
.149	.083	In this region,	
.155	.092	x = y	
.161	.102	exactly.	
.166	.111	1.042	1.042

* The values in this region are changing slowly, and rounding-off will give [illegible] possible these dimensions should be held.

coordinates are tabulated in Table III. Two such filters were fabricated and used for the feasibility tests.

Feasibility Tests:

Equipment

It was necessary to design and construct a mechanism which would hold the filter in place and rotate it sufficiently fast to obviate flicker and produce the necessary image integration. This device also had to be continuously adjustable in the vertical and horizontal planes, and be capable of adjustment of the filter to place it about the center of rotation.

The device consists of a Servo-Tek 1/20 HP motor controlled through a diode bridge circuit and rheostat, coupled through a timing belt and appropriate sprockets to the filter holder which is mounted in a large-diameter inner bearing race. The outer race is held fixed in a steel frame. The vertical adjustment is accomplished through levelling jack-screws, the horizontal by sliding the base on which the unit is mounted, through application of push-pull screw forces. The motor is capable of speeds up to 5000 RPM. It was determined that the speed necessary to overcome the objectionable flicker would lie between 600 and 2000 RPM, so that the gearing and timing belt combination limits the maximum rate to 2000 RPM.

Initial tests indicated serious vibration problems, and several methods were tried to minimize the effect on the aerial image. Finally, Vibra-Check, a material previously used on the Image Enhancement

TABLE III

TABLE OF COORDINATES FOR GAUSSIAN FILTER (Revised)

The following tabulation of coordinates is for the 1st Quadrant only; the dimensions are in inches.

x	y	x	y
.000	.002	.172	.123
.005	.0025*	.177	.132
.010	.0030	.183	.142
.020	.0040	.188	.151
.030	.006	.199	.170
.040	.008	.210	.188
.049	.010	.221	.204
.059	.013	.233	.221
.069	.016	.245	.237
.078	.020	.258	.253
.087	.025	.271	.268
.096	.030	.284	.282
.105	.036	.298	.296
.113	.043	.312	.311
.121	.050	.326	.325
.128	.058	.354	.3535*
.135	.067	.382	.382
.142	.076	In this region, x = y exactly	
.149	.085		
.155	.094		
.161	.104		
.166	.113	1.042	1.042

* The values in this region are changing slowly, and rounding-off will give values too much in variance with what is desired. If possible, these dimensions should be held.

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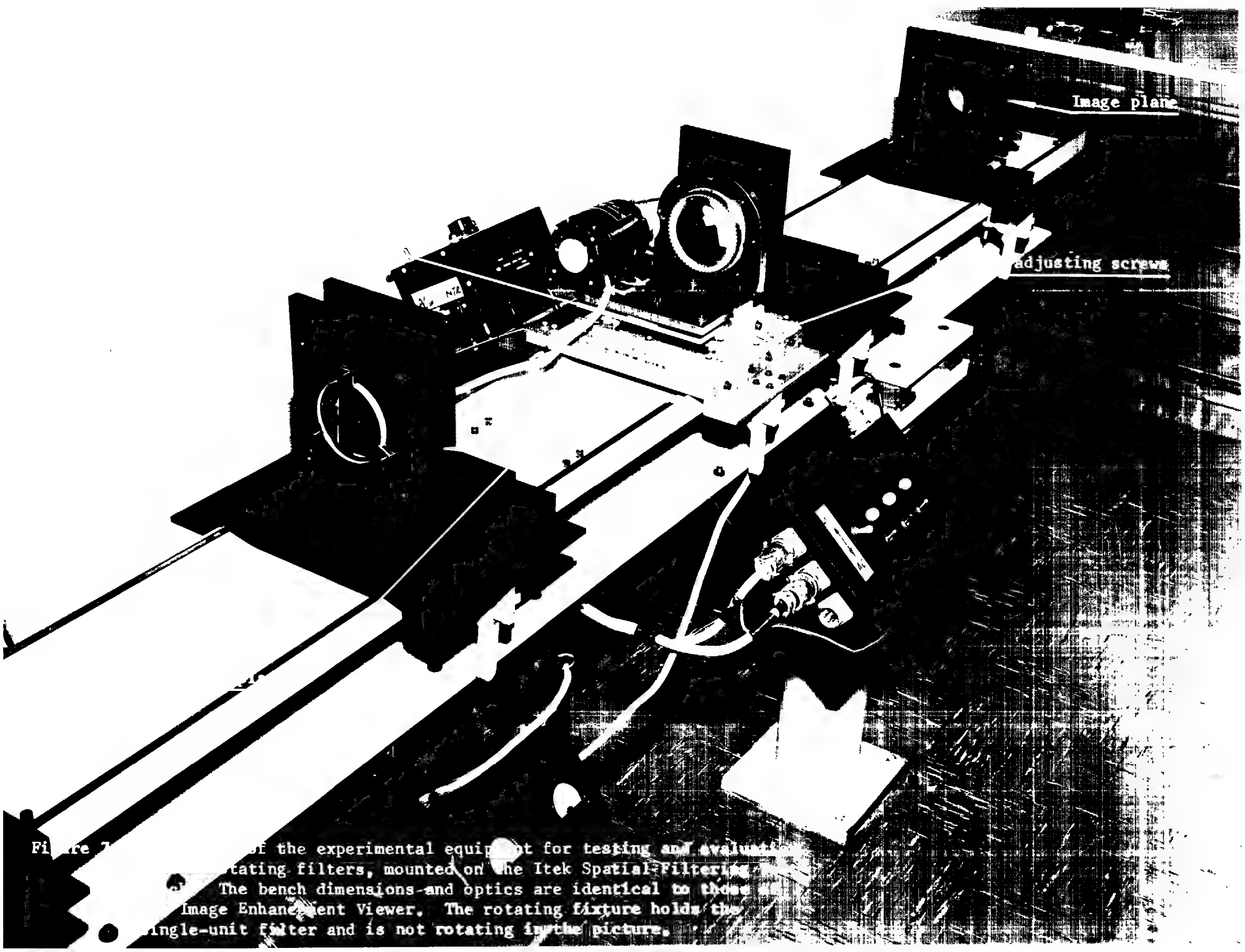
Viewer to eliminate building vibration, was installed, and the vibrations reduced past the point of affecting the filter evaluation. The Vibra-Check was bonded to both the rotating jig levelling plate and the movable base plate with Pliobond to prevent shifting during the centering and alignment operations.

A photograph of the rotating filter device and the optical equipment with which it was used is shown in Figure 7. The filter shown in the rotating device is a single-unit filter, about which more will be said later.

Filter Alignment

Preparatory to assessing the filtering properties of the rotating profiled slot, it was necessary to insure that it was precisely centered, about the center of rotation. This was accomplished as follows. A diffuse illumination backlighted the rotating filter while a set of achromatic doublets image the filter plane onto a slit of a scanning photometer. The output of the photometer was put onto a moving chart so that a permanent record of results was obtained. This also served as a check on reproducibility and on how well the filter remained aligned.

Initial problems in evenness of the backlight illumination were overcome, and the filter centered through adjustment of the set-screws in the filter adapter. The designed filter, as plotted in Figure 6, was found to be quite difficult to adjust, insofar as adjustments away from the center were required, since the set-screws did not provide this type of correction. Since the filter shape would be retained



Fi[illegible]re [illegible] of the experimental equip[illegible]t for testing and evaluati[illegible] [illegible]tating filters, mounted on the Itek Spatial-Filtering [illegible]. The bench dimensions and optics are identical to those [illegible] Image Enhancement Viewer. The rotating fixture holds the [illegible]ingle-unit filter and is not rotating in the picture.

(although the optimum filter transmission ratio would not obtain) it was decided to eliminate one of the opaque sections to facilitate adjustment. This was found to be more easily centered, although the centering operation was still found to be quite sensitive. Figure 8 is a photograph of two traces produced during these centering tests which are typical of approximately a score necessary to adjust the filter properly. One shows the filter to be slightly outside the center of rotation, the other to be exactly centered. The single-unit filter, while rotated at the same RPM* as the double unit, achieved only half as much beam-cutting, and this is evident on the trace, where the instrument stylus actually follows the "on-off" fluctuations of the photocell. The smooth portion at the center of the trace indicates exact alignment, since there is no "chopping", and hence no stylus jitter.

Filter Evaluation

Once the filter was centered, the incoherent illumination was removed, and the filter placed in the diffraction plane of a linear,

* RPM was measured with a General Radio Type 1531-A Strobotac. Most of the experimental determinations were conducted at or about 1000 RPM, and 1600 RPM was attained with the designed filter without experiencing any resolution loss due to vibration. It was found that after prolonged operation, the bearing grease viscosity dropped somwhat, and RPM increased by approximately 15% over the "cold" or starting speed.

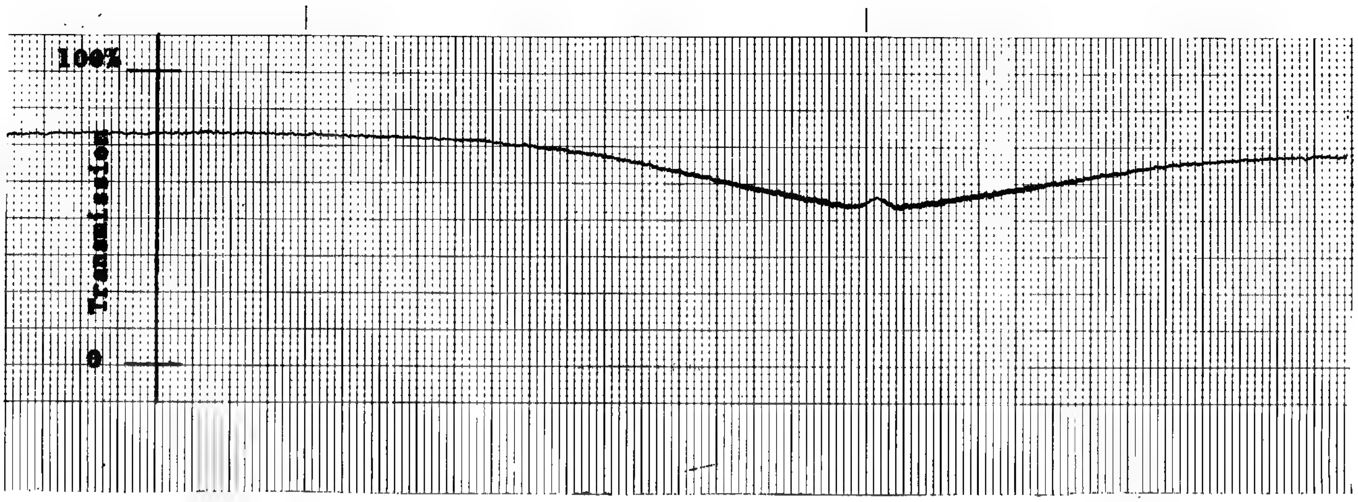


Image trace typical of filter which is rotating around but outside the center of rotation.

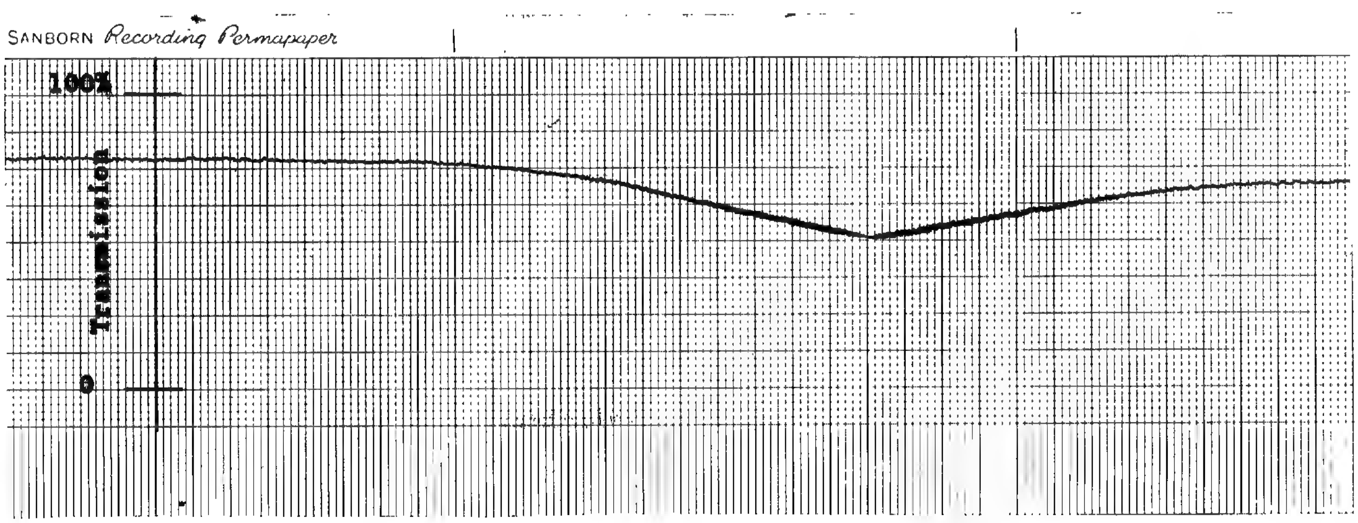


Image trace typical of a filter which is exactly centered, and rotating about the center of rotation.

Figure 8: Portions of typical image traces of a single unit filter made during centering tests. The trace magnifies the image 7.7 times.

coherent optical system identical to the Image Enhancement Viewer. Through use of the levelling jack-screws the lateral screw adjustment, the center of rotation was placed in congruence with the optical axis. This was done by considering the placement of the filter tip at the center of frequency space located precisely with the aid of a diffraction pattern of a Buckbee-Meers bar-target transparency.

The alignment was first carried out visually, then checked by photographing the aerial image of the bar-target while the filter rotated. From previous experience, coupled with the results of the centering tests, it was possible to deduce the degree and direction of misalignment and make the appropriate corrections. Once aligned, the image of bar targets and typical aerial photographs were examined visually and photographically. Having the results of the previous work on the 9019 program, a direct comparison with those results would serve to indicate filtering feasibility.

It was found that none of the filtered images, whether viewed directly or in photographs, were an improvement over the filtered ones, as obtained with the neutral densities produced for the 9019 program. Further, it was ascertained that a general lowering of contrast had resulted without a compensating increase in some other aspect of image quality; as a matter of fact, the photographic and visual images appeared "hazy".

It was decided to examine the image of a bar-target for various static positions of the filter. The filter was placed to point upward, downward, left and right, and the four positions photographed separately. A typical result in shown in Figure 9. It was found that this image type obtained in all four positions; the smearing

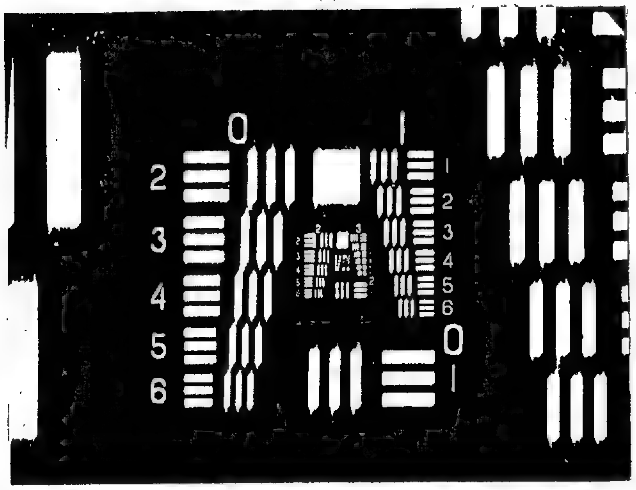


Image with spatial filter stationary and pointing vertically.

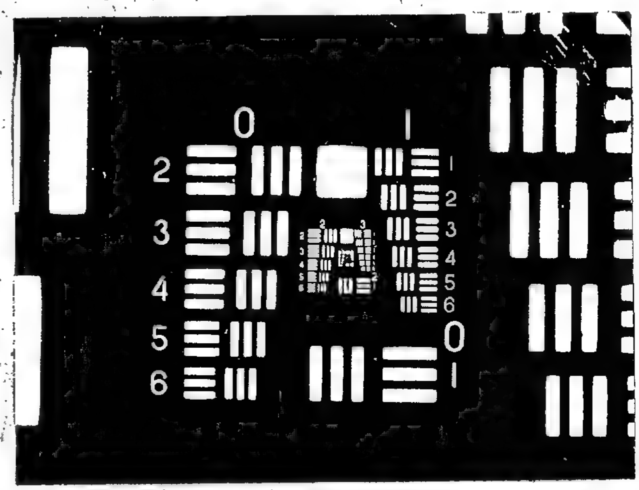
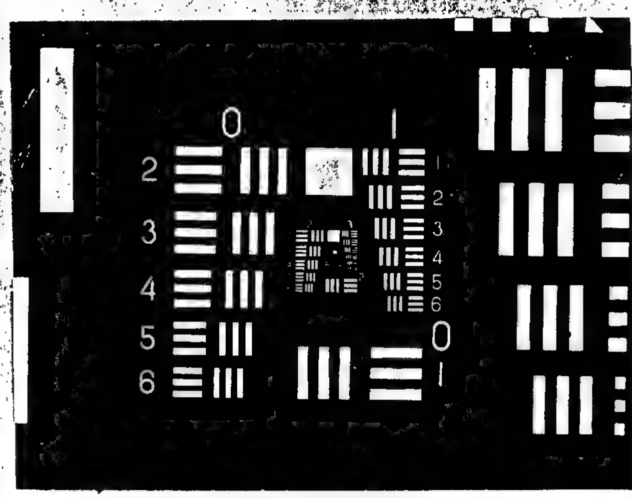


Image with spatial filter rotating at 830 RPM.



Unfiltered image.

Figure 9: Photographs (3x) of the image of a Buckbee-Meers Bar Target, illustrating the effect of low-frequency glint on the aerial image contrast.

or haze always occurs in the direction in which the filter points. Thus, while rotating, the entire image is blanketed by this "smearing" or haze light. Further, as the spatial frequency increases, the effect diminishes, thereby placing the trouble at the center of the system.

The explanation is simple when viewed in this light. Most of the energy is concentrated in the lower frequencies, particularly at 0 lines/mm, or along the optical axis. When the filter is appropriately placed, this light glints from the edge of the filter and specularly reflects over the entire image plane; it predominates at the lower frequencies. The net effect is to add light over the entire image field and thus produce a contrast loss. The effect is not as great at the higher frequencies, and no resolution loss is experienced. However, the over-all effect is to degrade the image. Comparison of the photographs in Figure 9 will illustrate the lack of image quality improvement.

There appears to be no way in which this degradation can be removed or minimized. If the filter is de-centered so that the center of the filter lies outside the center of rotation (which is assumed congruent to the optical axis) filtration will not be accomplished, since the center frequencies must be reduced in comparison with the higher ones. If the de-centering is such that the center of the filter occludes the center of rotation, the filter becomes a sharp cutoff, occluding filter and image tone is lost. The third possibility, that of misaligning the center of rotation with respect to the optical axis, produces effects which are a combination of filtering (occluding) and non-filtering. Since these effects will necessarily be assymetric with respect to frequency space, and since image tone will be partially lost, they do not constitute a solution to the problem.

It therefore is concluded that the method of frequency attenuation using rotating, profiled slots is not feasible, and frequency attenuating filters must be fabricated with the aid of density distributions placed on glass, the difficulties of which have already been discussed in the 9019 final report.

Summary of Feasibility Studies

The feasibility of production of profiled slots for providng a given transmission distribution has been demonstrated, and centering and alignment techniques developed. The evaluation of the filters, however, has divulged a basic incommensurability with the system which renders the rotating, mechanical filters infeasible. This phenomenon is the glinting or reflection of low-frequency image energy onto the image plane which reduces the contrast of the image. No remedy for this effect has been found, and the research on rotating, profiled slots for frequency attenuation has been terminated.

4. Theoretical Studies and Experimental Edge Evaluation

Phase I called for a quantitative evaluation of the sharp cutoff, occluding filters installed in the Image Enhancement Viewer. In anticipation of this, several basic studies were undertaken, the objectives of which were to provide an analytical framework for the evaluation. Among the topics taken into consideration were the analytical descriptions of images of a non-sharp pulse passed through Gaussian and sharp cutoff, occluding filters. Near the end of Phase I, in view of the difficulty of interpreting edge behavior in terms

of pulse analysis, the image of a photographic edge passed through sharp cutoff, occluding filters was formulated. This particular analysis required computer aid, and at present is incomplete; i.e., the analytical expressions for aerial image intensity incorporate several tabulated functions and these have not been combined and the image functions plotted and assessed at this writing.

Collaterally, to aid inthe evaluation of the rotating spatial filters, the image of a sharp pulse passed through a Gaussian filter was formulated and used in the interpretation of filtered bar-target images.

A precise assessment of Image Enhancement with the present (improved) equipment was begun. It was determined that there was no way of enhancing an edge with the use of sharp cutoff, occluding filters alone, but that by combining filtered and unfiltered images, there was a technique of image enhancement available. These techniques (exposure addition and transmission multiplication) were described analytically and preliminary verifying experiments carried out. Exposure addition was subjected to very precise experimentation. The extensive experimental data accumulated on exposure addition remains to be analyzed and related to the general enhancement concept. Transmission multiplication was not attempted because present equipment was not capable of overcoming the problem of registration.

Experimental methods of producing a photographic edge of predetermined characteristics were developed, and a series of test edges produced. These edges were later used in the enhancement-through-exposure-addition experiments.

A long step towards the evaluation of the sharp cutoff, occluding filters was taken in Phase I, in combination with a tentative formulation of the enhancement problem. Taken together with the difficulties experienced in the evaluation of the rotating mechanical filters, there was simply insufficient time to complete these studies with the rigor which the problem merits. It is felt that these studies should be extended and finished, to complete our understanding of the enhancement process and to provide a quantitative evaluation of the filters and their use in enhancement.

5. Recommendation for 9043 Project Continuation

Equipment requirements

In view of the fact that Phase I proved the infeasibility of the rotating mechanical filters, Phase II as originally written and set forth in the contract cannot be carried out. However, because of the general usefulness of the equipment, it is felt that with additional modification, its maximum capabilities could be realized.

One of the unofficial complaints about the instrument's use at the contracting agency's facility was the high degree of skill required for its operation and adjustment. Subsequent engineering modifications reduced the need for this skill, but with the latest engineering changes, several modifications could again be usefully applied. As an instance, consider the new angular and linear measurement capability. It is now important to be able to rapidly and positively position the object transparency in the viewing field for purposes of mensuration, and to do this with precision. The present system uses mechanical

cables and through sets of bevel and worm gears positions with accuracy, but not very rapidly and very seldom smoothly. Pairs of selsyns can easily be installed in this unit which will permit not only much more smooth and precise changes of object position, but also with a considerably less expenditure of time and energy. This particular modification would also release the object unit from its present location (because of the necessity for staying within the cut-out of the I-beam) and permit separation of the collimating lenses. This not only corrects the optical system to the proper Fraunhofer diffraction mode, but allows auto-collimation in adjustment.

Thus there is a definite need to simplify the operation of the Image Enhancement Viewer and maximize its very useful spatial filtering properties.

Engineering modifications

With the end to making the instrument more accessable to unskilled personnel, and rendering the total operation one of convenience and improved usefulness, the following alternative program is recommended to replace the program determined for Phase II:

1. Re-wire the Source Unit so that the input and output power leads and the additional control wiring pass through an Amphenol connector located on the forward unit plate.

2. Replace the present Object Unit with a new unit incorporating the following features: a) Selsyn positioning of the object vertically and horizontally, a total of two inches travel in both directions, b) separate the collimating lenses in order to operate in the correct Fraunhofer diffraction mode and to facilitate auto-collimation adjustment. The unit will be able to handle carriers for both film and plates.

3. Install two new occluding filters in the filter unit, to be of 0.020 and 0.010 inches in diameter, approximately. This will extend the filter range by a factor of four (4), and should prove very useful on edges of poor gradient characteristics.

4. Replace the three wooden bipods by two steel pedestals which will be anchored permanently at the contracting agency's facility. This will be shock-mounted as per the agency's building requirements. A Photograph of such an installation is shown in Figure 7 of this report.

5. Replace the present control panel by a new unit which is in the form of a wheeled console. This will incorporate all the power supplies and associated switches and transformers. This will place all electrical power and control devices together and will facilitate maintenance and simplify operation.

6. Provide current-regulation to the DC power supply which eliminates the necessity for prolonged and supervised "warm-up" time by a skilled operator.

7. Install necessary cabling for modifications.

8. Carry out minor miscellaneous engineering changes which are not sufficiently important to list here.

9. Metal-finish Phase I unit and all new proposed items compatibly to complete equipment metal-finishing requirements.

10. Prepare an operating and maintenance manual which will bring the equipment up to date and permit full utilization of the latest modifications. The results of enhancement and spatial filtering studies will be incorporated as they apply.

Enhancement Techniques and Evaluation

It is recommended that the analytical evaluation of the sharp cutoff, occluding filters and the formulation of enhancement with their use be completed. These studies will facilitate optimum use of the equipment. Actually, since most of the experimental work has been initiated, the majority of these studies will be concerned with the

analysis and interpretation of experimental data, together with certain definitive experiments required to check the conclusions. The results of these, as they apply, will be incorporated in the operating and maintenance manual previously proposed.

Alternate Phase II Schedule

In view of the generally straightforward engineering changes proposed, the original delivery date of the Phase II program can be met. This calls for completion by 31 January 1963, including all hardware, reports, and manuals. Provided the alternative Phase II is approved by 15 September, no additional time is required. A subsequent approval date would necessarily set back the 31 January date.

Alternate Phase II Cost Estimate

Since many of these modifications would have been included in the original Phase II program, and since the relative complexity of the engineering changes is approximately the same, the cost estimate provided with the Phase II program will not require revision or amendment. No increase in contract funding is required.